The Little-Endian OpenPOWER Software Development Environment

Dr. Michael Gschwind
Senior Technical Staff Member & Senior Manager
IBM Power Systems

OpenPOWER Summit 2015
San Jose, CA | March 17-19
OpenPOWER ecosystem

- Enable rich ecosystem of hardware vendors
  - Standardized hardware interfaces
  - Common, open firmware interfaces

- Open source system software stack
  - Data center operators rely on tuning SW stack
  - Enable server ODM vendors to create offerings
  - Operating environment built on Linux and KVM

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A New OpenPOWER Linux Environment

- OpenPOWER is not traditional Power Linux with a new name
  - Significant discontinuity and fresh start
  - new environment “ppc64le”
    - Firmware, Hypervisor, data layout, source code, ABI, APIs

- What changes for application developers?
  - Byte order
  - New ABI
  - Vector programming API

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The New Byte Order

- Little-endian data format and programming interfaces
  - Simplify porting of applications previously locked to Intel x86
    - Large-scale data center applications
    - Application source code dependences
  - Access data repositories storing binary data written by Intel x86
    - In-storage data base formats
    - Data sharing with mobile devices
  - Simplify data sharing with I/O devices originally from LE ecosystems
    - Easily exploit I/O and accelerators designed for PCs and mobile devices

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The New OpenPOWER Application Binary Interface (ABI)

- Optimizations driven by hardware and software evolution
  - Align with the broader ecosystem
  - Create hardware optimization opportunities and synergies

- Optimize for modern code patterns
  - More classes, abstraction
  - Shorter function lengths
  - More indirect calls

- New capabilities as delta over starting point: PPC64 / AIX ABI
  - Established, tested production code
  - Commonality and maintenance across LE, BE and AIX where feasible
  - Minimum disruption for tooling: GCC, XL, Java, LLVM, libffi, PyPy, ...

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The new ABI

- Application development: no change
  - for applications written in Fortran, Pascal, C, C++, C#, Java, Python, Ruby, Spark
  - minimal change (0-4 lines) for assembly programs

- Align with other Linux environments to simplify migration

- Simpler and shorter code

- Improved performance and ease of adoption
  - During initial LE Linux bringup, 40,000 packages ported over short period

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ABI Improvements: simplify and accelerate

- Global data management with the Global Offset Table
  - Initialize pointer to GOT without functions descriptors
  - Optimize GOT pointer update on cross-module calls
  - Expand addressing range with “Medium Code Model”
  - Exploit Displacement Fusion and avoid GOT overflow code

- Pass more registers in their native registers
  - Reduce abstraction penalty (“same performance as builtin types”)
  - OO languages wrap types in abstract class
  - Previously classes handled differently from builtin types
  - ELFv2 passes up to eight class members in registers
  - Return function results in same register(s) as first input parameter

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Medium Code Model

- “Medium code model” addresses growing application size
  - Expand GOT data dictionary to up to 4GB

- Avoid expensive GOT overflow > 64KB (8k variables) per module
  - Size originally set to POWER ISA offset size (16b)

- Enable applications with up to 500M variables per module
  - “Beyond RISC” using Displacement Fusion in Power8

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Beyond RISC: Displacement Fusion

- Combine multiple instructions into single internal instruction
- Compound instruction executes as a single hardware operation
- Increased addressing range with RISC fixed-width instr. advantage

```plaintext
addis r3=r2, D1@ha
ld    r3=r3, D1@l
```

Displacement fusion

```
ld    r3= r2, D1
```

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Example OO method with abstract data types

- **Work instructions in green**
- **Overhead due to passing abstract data types via memory in red**

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The Little-Endian Vector API

- Vector API builds on OpenPOWER Little-Endian Data Model
  - Focus on programmability – consistent little-endian view
  - Focus on ease of sharing code with other little-endian ecosystems

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Little-Endian Vector API Implementation

- Common Vector Programming API across GCC, LLVM and XL
  - Vector builtins as operators
  - Enable compilers to optimize expressions with vector operators

- Vector API code models are programmer abstractions
  - Common LE/BE compiler backend...
  - ... recognizes and optimizes the different conventions

$$f^{-1}(s(f(x), f(y)))) \Leftrightarrow s(x,y)$$

Technical details:
- “Supporting Vector Programming on a Bi-Endian Processor Architecture”, LLVM 2014

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OpenPOWER Environment available now

- Collaborative innovation already changing industry
  - Major data center stakeholders joining OpenPOWER
  - Little-endian Linux on Power available from three major distros
    - Over 40000 open source packages and ISV applications ported

- Redefined software stack: Firmware, Hypervisors, OS, Applications
  - Little-endian data model for simplified application porting
  - New ABIs and APIs support developers in exploiting platform

- New OpenPOWER environment enables
  - Ease-of-use and out-of-box performance
  - Exploitation of new Power8 hardware features

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